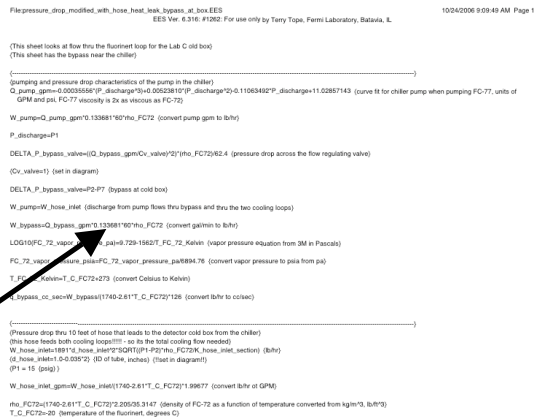
Lab C Fluorinert Loop

- Looked at pressure drop and thermal loads
  - Performed calculations using EES Simultaneous Equation Solver
    - Used standard pressure drop equations form Crane 410 Technical Paper
    - Used temperature dependent Fluorinert properties provided by 3M
  - Pressure drop model includes
    - Chiller pump flow vs. pressure curve fit for Fluorinert from chiller manufacturer
    - Pressure drop thru various components
      - Hose to/from chiller
      - Piping inside cold box
      - Valves for bypass, isolation, and flow control
      - Curve fit for pressure drop across detector based on 6 channel test


File:pressure_drop_modified_with_hose_heat_leak_bypass_at_box.EES 10/24/2006 9:09:49 AM Page 1
EES Ver. 6.316: #1262: For use only by Terry Tope, Fermi Laboratory, Batavia, IL

{This sheet looks at flow thru the fluorinert loop for the Lab C old box}
{This sheet has the bypass near the chiller}

{pumping and pressure drop characteristics of the pump in the chiller}
Q_pump_gpm=-0.00035556*(P_discharge^3)+0.00523810*(P_discharge^2)-0.11063492*P_discharge+11.02857143 {curve fit for chiller pump when pumping FC-77, units of GPM and psi, FC-77 viscosity is 2x as viscous as FC-72}

W_pump=Q_pump_gpm*0.133681*60*rho_FC72 {convert pump gpm to lb/hr}

P_discharge=P1

DELTA_P_bypass_valve=((Q_bypass_gpm/Cv_valve)^2)*(rho_FC72)/62.4 {pressure drop across the flow regulating valve}

{Cv_valve=1} {set in diagram}

DELTA_P_bypass_valve=P2-P7 {bypass at cold box}

W_pump=W_hose_inlet {discharge from pump flows thru bypass and thru the two cooling loops}

W_bypass=Q_bypass_gpm*0.133681*60*rho_FC72 {convert gal/min to lb/hr}

LOG10(FC_72_vapor_pressure_pa)=9.729-1562/T_FC_72_Kelvin {vapor pressure equation from 3M in Pascals}

FC_72_vapor_pressure_psia=FC_72_vapor_pressure_pa/6894.76 {convert vapor pressure to psia from pa}

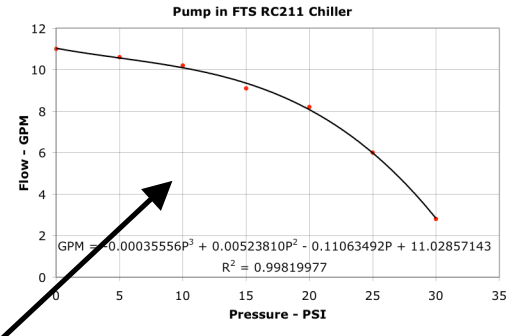
T_FC_72_Kelvin=T_C_FC72+273 {convert Celsius to Kelvin}

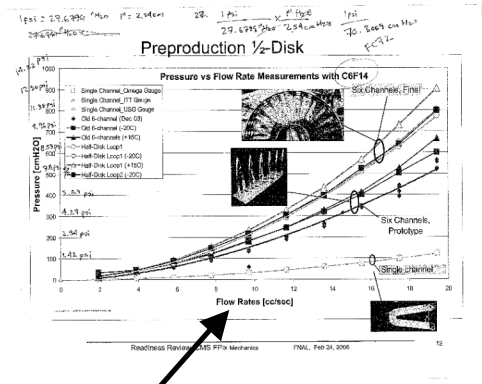
Q_bypass_cc_sec=W_bypass/(1740-2.61*T_C_FC72)*126 {convert lb/hr to cc/sec}

{Pressure drop thru 10 feet of hose that leads to the detector cold box from the chiller}
{this hose feeds both cooling loops!!!!! - so its the total cooling flow needed}
W_hose_inlet=1891*d_hose_inlet^2*SQRT(P1-P2)*rho_FC72/K_hose_inlet_section) {lb/hr}
{d_hose_inlet=1.0-0.035*2} {ID of tube, inches} {Tsat in diagram!!}
{P1 = 15 (psig) }

W_hose_inlet_gpm=W_hose_inlet/(1740-2.61*T_C_FC72)*1.99677 {convert lb/hr ot GPM}

rho_FC72=(1740-2.61*T_C_FC72)*2.205/35.3147 {density of FC-72 as a function of temperature converted from kg/m^3, lb/ft^3}
T_C_FC72=-20 {temperature of the fluorinert, degrees C}





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Lab C Fluorinert Loop

- Thermal model includes
  - Conduction thru 1 inch of poor insulation on chiller hose and convection to the ambient
  - 36 W heat load per 6 channels for 144 W total
  - Glycol loop assumed to intercept heat before it reaches fluorinert plumbing in cold box - chiller has several times the required cooling power so assumption is safe
- Key flow loop features
  - Bypass near cold box that allows majority of flow to return to chiller
    - Fluid only spends a few seconds in transit from chiller to cold box so it does not warm up
  - Isolation valves and flow control valves for each loop
    - Allows loops to operate independently
  - Particulate filter and molecular sieve with isolation valves
    - Want to keep water out of system to prevent corrosion
  - Relief valves to protect detectors from over pressure

FTS System Chiller
1350 W @ -20 C

Red = Calculated pressures at various points

Blue = Calculated volumetric flow rates at various points

Purple = Calculated thermal quanities

Room temperature RTD TE AE Room humidity

= Pressure Indication PI

= Calibrated RTDs TE

= Differential Pressure Indication DPI

PI TE 0-60 psig
18.56 psig

TE PI 0-30 psig
1 psig

476 W total heat load (332 W from insulated hoses and 144 W from detectors)
ΔT = 0.50 C (Overall ΔT is small due to large flow rate from chiller)

Supply & return hose from chiller
15 ft. of ~0.75" ID hose
Use 3M recommended hoses such as Tygon C-544-A I.B. or stainless steel flex hose.
Insulated with 1" of pipe insulation.

537 cc/sec

166 W hose heat leak
ΔT = 0.20 C

29 psig relief sized to relieve chiller pump
½" Circle Seal 5100 with Butyl o-ring
Vent of relief valve should be piped into container to hold fluorinert in the unlikely event it opens

Colorado Cold Box

30.06 cc/sec

Pressure instruments located outside cold box with capillary tubes tied into main tubing

0-30 psid DPI

PI 0-60 psi

Flow control valves, with variable Cv from 0-2. Allow the flow rate thru each loop to vary and for the loop to be isolated.

29 psig relief
1/4" Circle Seal 5100 with Butyl o-ring
Relieves liquid between isolation valves

36 W

36 W

2nd cold box for filters and plumbing

4.09 psig

Bypass valve to balance flow between bypass and detector loops. Cv ranging from 0 to 5 as it opens. Bypass loop shown inside cold box to reduce heat leak.
477 cc/sec
@ Cv = 3

Relief valve with set point based on pressure rating of components
1/4" Circle Seal 5100 with Butyl o-ring
Relieves liquid between isolation valves

Heater for molecular sieve regeneration

0- 5 psid DPI

15.46 psig

14.65 psig

Isolation valves, Cv = 2

0-30 psid DPI

PI 0-60 psi

29 psig relief
1/4" Circle Seal 5100 with Butyl o-ring
Relieves liquid between isolation valves

4.61 psig

5.92 psig

ΔT = 1.36 C across 6 flow channels
36 W generated by 6 flow channels

36 W

1 meter of 0.173 in. ID aluminum pipe to each detector

15.03 cc/sec

12.82 psig

14.13 psig

15.03 cc/sec

30.06 cc/sec

60 cc/sec

0.7 meter of 0.305 in. ID aluminum pipe

1 meter of 0.305 in. ID aluminum pipe

1 meter of 0.173 in. ID aluminum pipe to each ½ disk

Isolation valve for vacuum pump out of molecular sieve during regeneration

Sintered metal particulate filter (10-50 micron) and molecular sieve (Silica Gel). Pressure drop across filters should not exceed 1 psi for 1 GPM flow. Isolation valves should have a Cv of 2. 3M claims molecular sieves designed for water removal from refrigerants work with fluorinert. Filter and valves should be in a cold box to reduce heat leak and placed after bypass and before flow goes to detectors.

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- Suggested materials and practices
  - 3M has very good material compatibility info and general guidelines
  - To prevent leaks
    - Weld everything possible
    - Epoxy pipe thread joints
    - VCR style metal seal fittings would be a good choice for a leak free worry free fitting
    - O-ring seals can work, but have issues because many o-rings swell in the presence of Fluorinert or do worse things
  - Valve selection
    - Ideal valve for worry free leak free operation would be a stainless steel metal bellows seal to atmosphere valve
    - Must be careful with valves that have plastic/rubber components because Fluorinert might compromise valve operation